WAVECONTROL

EMF Assessment of Railway Rolling Stock

APPLICATION NOTE

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Wavecontrol solution for EMF Assessment of Railway Rolling Stock in accordance with standards.

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1. Introduction

In railway environment, exposure to low frequency electromagnetic fields comes from three main sources; the rolling stock, fixed installation and signalling equipment, which must be assessed to ensure that the public users and railway workers are not overexposed to these fields that could lead to electrostimulation effects. Contribution of the signalling equipment is very minimal in comparison to the other sources and can be neglected during assessment.

As emission generated by these sources is within the frequency range from DC up to 20 kHz, assessment of EMF is restricted to this range as specified in the EN 50500 standard from CENELEC and the IEC 62597 from IEC [1] which are covered in this application note. Within this frequency range, magnetic field is the dominant field, hence the electric field is neglected during assessment as the E field strength will typically comply with EMF exposure levels.

This application note describes exclusively the procedures for measuring magnetic field levels generated by the rolling stock used in the railway environment by a rolling stock manufacturer following the EN 50500 (IEC 62597) standard. The measured EMF exposure levels are compared to the public reference levels defined in the 1999 EC recommendation, ICNIRP 98 guidelines and other regional standards as many rolling stocks are designated to be sold internationally. It was also assumed that not all railway workers are EMF workers, therefore their exposure assessment fall within the general population category. Moreover, compliance with the public limits means compliance with the occupational ones, as the public limits are more conservative.

Target audience: Rolling stock manufacturers, test labs and inspectors/auditors of rolling stocks.

1.1 Reference Standards

The standard used for the present application note is the CENELEC [2] standard as follows:

- EN 50500: 2008 “Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure”.

The international IEC [3] equivalent can also be used as it describes the same measurement procedures and conditions:

- IEC 62597:2019 “Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure”.

2. Measurement Instrument

The measurement instrument must comply with the IEC 61786-1.

2.1 Device Requierements:

The IEC 62597 and EN 50500 specifies requirements for the measurement instruments, which are summarized and compared with solution proposed by Wavecontrol.

Standard requirements (IEC 62597 and EN 50500)	Wavecontrol solution (SMP3 + WPH-DC and WP-Series probes)
Compliance with IEC 61786-1	Yes
Static (DC) H field. Variable (AC) H field up to 20 kHz.	WPH-DC probe WP400/WP10M (using 20 kHz Bandwidth)
Tri-axial (isotropic) probes for AC + DC 100 cm^2 sensor area for AC	Yes
Time-domain evaluation (weighted results) – Recommended by standard	Weighted Peak/RMS Method
FFT analysis (Hanning window)	Yes (resolution as low as 0.1 Hz)
Sampling frequency > 40 kHz	Approx. 1 MHz (WP400) 25.6 MHz (WP10M)
Data logging	> 1 million samples
Dynamic range (5 % - 200 %)	Yes (better)
Isotropy: 5 %	
Linearity: < ± 5 %	
Measurement uncertainty < 20 %	< 7 %

2.2 Evaluation methods:

DC field: Measurement of static magnetic field is done by summation of the three components of the field measured using the formula below:

$$H = \sqrt{{H_x}^2 + {H_y}^2 + {H_z}^2}$$

The standard recommends using an isotopic (triaxial) probe.

AC field: According to international standards (ICNIRP and IEC), measurement of AC magnetic fields is done using either frequency domain evaluation method (FFT using a Hanning window) or time domain evaluation method (WPM).

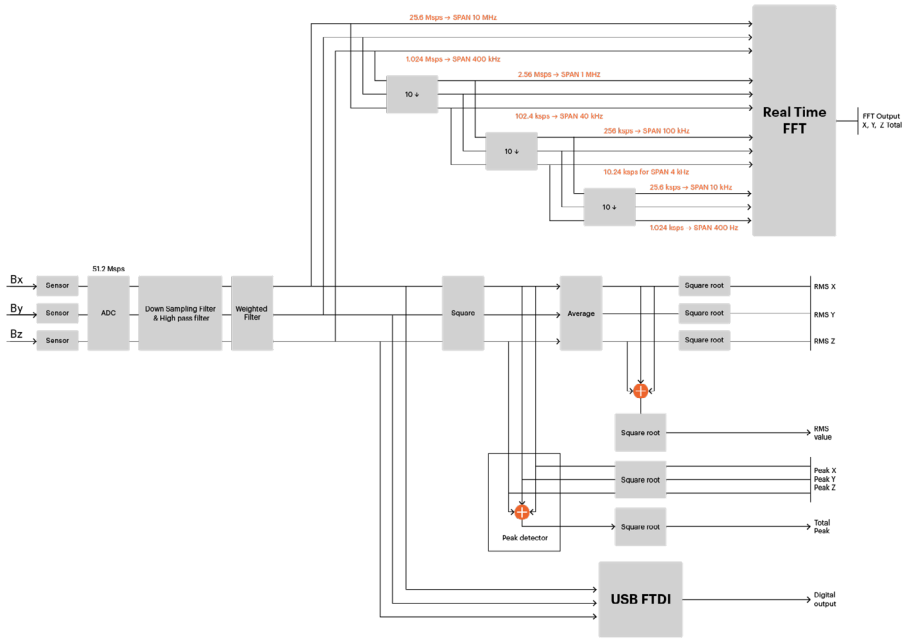
The frequency domain method overestimates H field strength as the railway environment is characterized by pulsed and complex non-sinusoidal waveforms. The application of the Weighted Peak Method is more realistic in many cases as this method takes into account the amplitude and phase of the spectral components that make up the signal. Hence, standards recommend using this method.

2.3 Wavecontrol Solution for Railway Assessment.

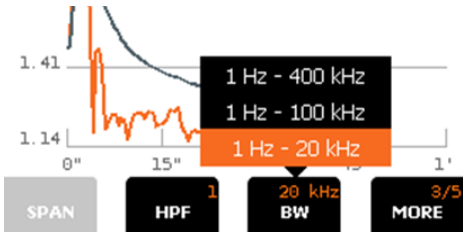
To perfectly meet these requirements and evaluation methods, the solution offered is the SMP3 + WPH-DC + WP400/WP10M probes.

The SMP3 meter from Wavecontrol implements the Weighted Peak Method using real-time digital signal processing to obtain a direct weighted percentage with respect to the limits which represents the exposure index.

Using the WP400 and WP10M field probes, the SMP3 has three detectors: RMS detector for weighted RMS value, Peak detector for weighted Peak value and an FFT generator to compute the FFT of the signal, thus providing a spectrum (frequency domain) view of the signal.



Additionally, the SMP3 allows configuring the measurement frequency bandwidth up to 20 kHz to perfectly comply with the frequency range defined in IEC 62597 and EN 50500.

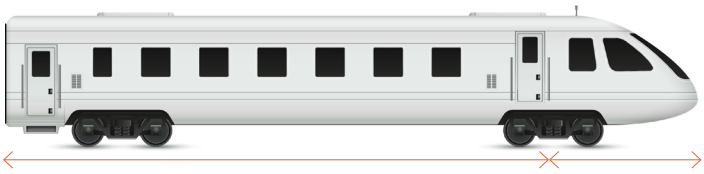


Note: SMP2 can also be used but only with the WP400 probe and does not offer the BW selection.

3. Anatomy of the Rolling Stock

The rolling stock is divided into two main zones:

- Zone A: Passenger area (non-restricted access to general users).
- Zone B: Worker area (driver and technicians' accessible areas).



3.1 Zone A: Passenger (public or non-restricted) Area

In this area, there are many potential sources of EMF which include the converter (traction and auxiliary), compressors, inductors, the transformer, the bogie (mag-braking system, brake discs, brake resistor, actuator, axle and bogie motor), traction motor, traction motor cable (standing area) and traction motor disconnection point, high voltage unit and power cables (top and bottom), train battery and charger, displays and the wagon crossing area.

Measurement of the bogie and mag-braking system of the rolling stock

Note: Usually, the converters and brake systems are the areas with highest magnetic field levels.

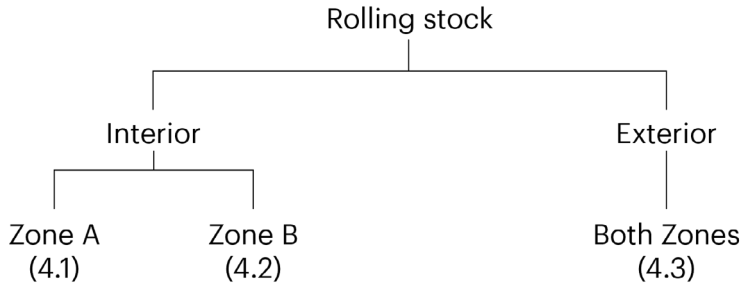
3.2 Zone B: Worker Area (Restricted to driver and technicians)

The restricted areas are usually only accessible to drivers and maintenance personnel. The main sources of EMF in these areas include the driver cab area, door, seat, air conditioning and heating systems, and traction motor cable.

Measurement of the driver cab and sitting area using the portable EMF meter

4. Measurement Procedures of the Rolling Stock

The interior and exterior of rolling stock must be measured following the procedures below:



4.1 Measurement for Interior (Zone A: Public area)

For zone A, measurement must be done at the closest possible points to the emission sources of the train as specified in 3.1, where the public can be. Measurement must be taken at heights of 0.3 m, 0.9 m and 1.5 m above floor level. The horizontal distance to the walls is 0.3 m or at a minimum distance (>0.3 m) where the public can be.

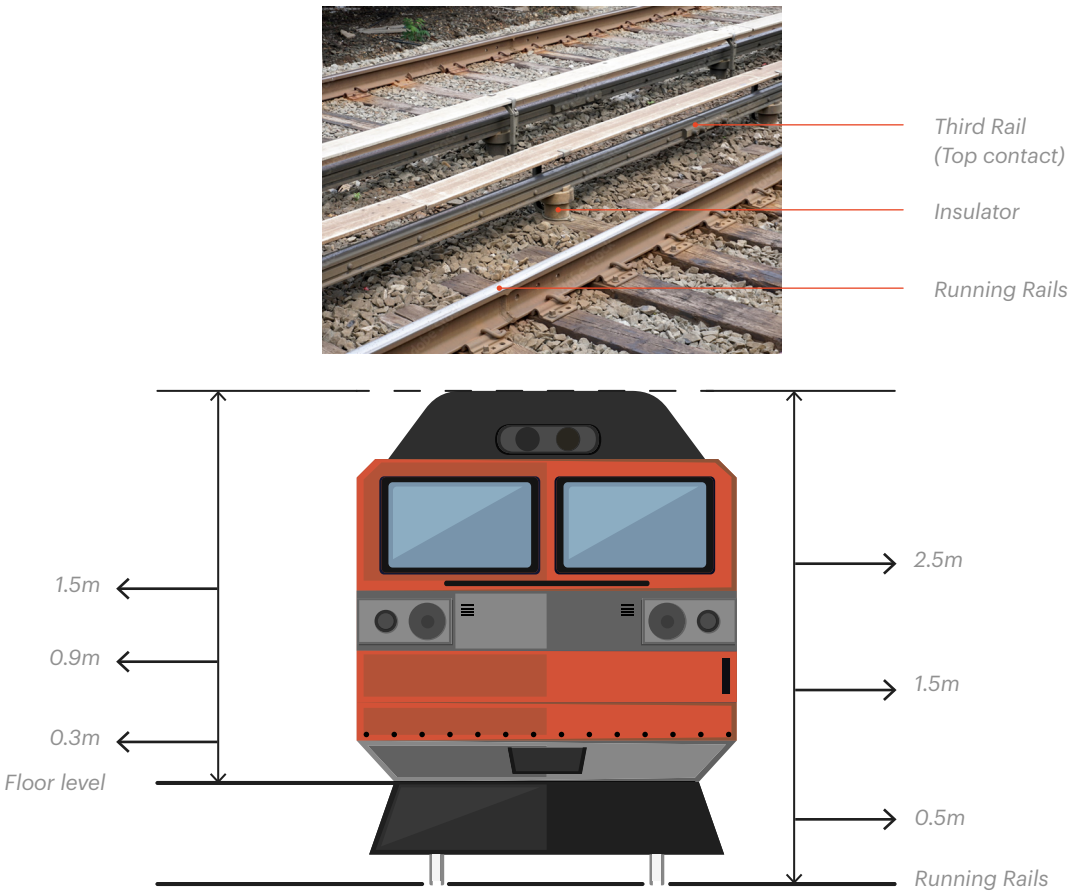
Simultaneous measurement heights at 0.3 m (public area), 0.9 m and 1.5 m (public and worker areas)

4.2 Measurement for Interior (Zone B: Worker area)

For zone B, measurement must be done at the closest possible points to the emission sources of the train where workers (such as the driver and other maintenance staff) can be found during normal train operation (see section 3.2). The measurement heights above the floor shall be 0.9 m and 1.5 m, with a horizontal measuring distance of 0.3 m to the wall or at the minimum distance where the workers can be.

4.3 Measurement for Exterior (Both Public and Worker areas)

When measuring the exterior of a rolling stock, the conditions for exposure are the same for both public and workers, hence, the measurement procedure is same for both zones. Measurement must be done at a horizontal distance of 0.3 m to the train enclosure at the closest possible position of the sources of emission of the train. The measurement heights are 0.5 m, 1.5 m and 2.5 m from the top of the running rails and should be done on both sides of the rolling stock for public access.



Interior measurement heights (from floor level) and Exterior measurement heights (from top of running rails)

Note: The measurement of the rolling stock interior for both Zones A and B must be done under standstill and dynamic conditions (see section 4.4). Measurements of the exterior is done only for standstill condition.

4.4 Test conditions for the rolling stock

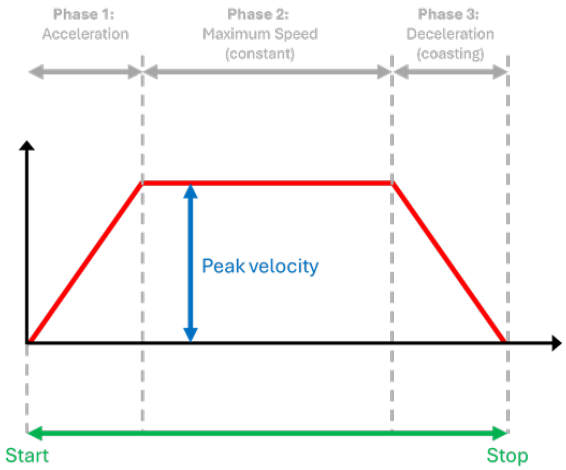
The test must be done only under normal train operations: Standstill and dynamic conditions.

4.4.1 Standstill condition

This is measurement done when the rolling stock is not moving, however, all traction circuits are energized but not operating. Under this condition, auxiliary circuits and relevant appliances (such as air conditioning and heating units, lights, electric generators) shall be active and operational.

4.4.2 Dynamic condition

Measurements are done on the rolling stock in a trapezoidal form, starting from a stationary position with maximum acceleration to maximum speed, decelerating (coasting) and maximum electrical brake to stop.



Under the dynamic condition, the traction circuits must be energized and operating, likewise the auxiliary circuits and all the appliances must be active and operational. Measurements must be done without the influence of other rolling stock or any external field source that is not part of the wagon being tested. Also, electrical braking systems using circuits different from those in the electrical propulsion systems tested during acceleration must be tested independently.

Note: The emissions from onboard equipment, the third rail, or the catenary each affect the measurement results of rolling stock. While the electromagnetic fields from onboard equipment will vary with the device's current, the fields from the catenary or third rail will vary based on the number of cars and the current.

4.5 Measurement execution for the rolling stock

All three axes of the magnetic field must be measured with one axis in parallel to the rails. For the rolling stock, the measurements should be done as follows:

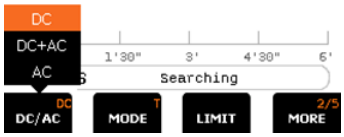
- All three axes of H field must be measured in standstill condition for a duration of 30 to 60 seconds (for both the interior and exterior of the rolling stock).
- All three axes of H field in the dynamic mode must be measured with a deceleration for a duration of 10 seconds (only applicable to the interior of rolling stock).

Note: For each measuring points and conditions, a single measurement is sufficient.

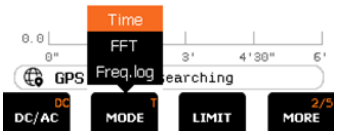
5. Rolling Stock Measurement Plan

The rolling stock assessment test plan should be done as follows:

1. Identifying all sources of electromagnetic field to be analysed (for example, transformers, inductors, electric motors, converters, and power cables). This information is obtained from the engineering design team, and these include:
    - Expected frequency range (DC – 20 kHz).
    - Sources dependent on operating conditions of the train.
    - Any external supply (such as catenary or third rail).
2. Based on the standard requirements and determination of the EMF sources established in the rolling stock engineering design, the measurement instrument is chosen.
3. Measure the external field sources (background levels) by doing a pre-scan of the measurement environment. It must be ensured that the field levels are minimized (i.e., << 10 % of the limit).
4. Place the SMP device at standard-specified heights and horizontal distances for the different zones and perform measurements under all possible test conditions using the WPM. To speed up the process, multiple SMP devices on a single tripod can be used to perform measurements at different heights (see sections 4.1–4.3). Measurement using the SMP can be done as follows:
    - Connect the probe (WPH-DC for DC measurement and WP-Series for AC).
    - Go to MENU -> MEASUREMENT OPTIONS and set Measurement time.
        - DC Magnetic field measurement
            - In the dynamic menu **AC/DC**, select **DC:**

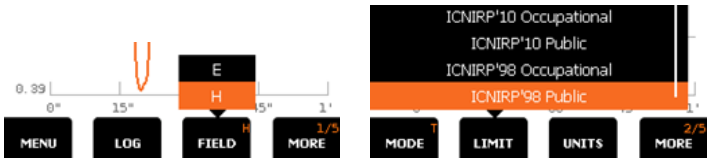


            - Set **MODE** to **TIME:**



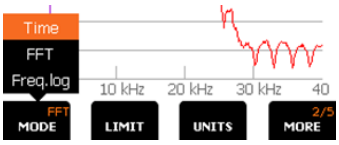
            - Select **LIMIT** (if required).
        - AC Magnetic field measurement.
            - Set **HPF** to 1 **Hz** and select **BW** up to **20 kHz:**

- Set **FIELD** to **H** and select the **LIMIT (ICNIRP 98/2010 General Public):**

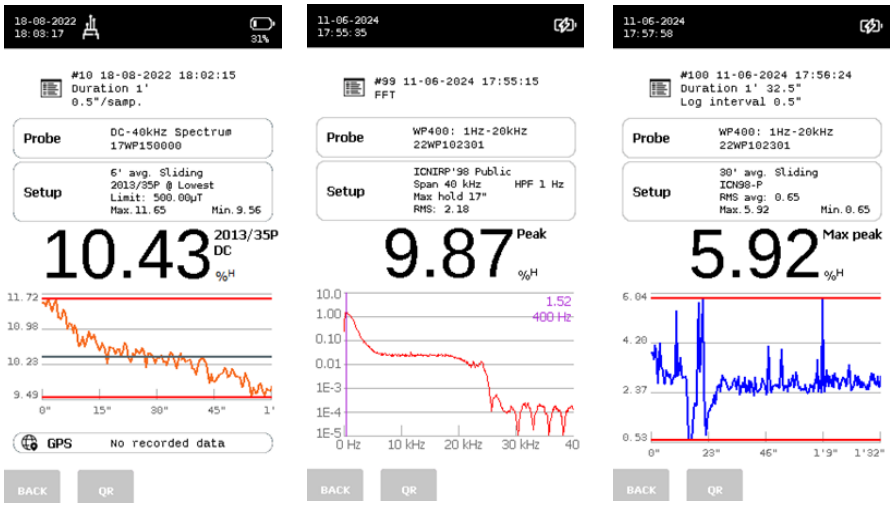


- For FFT analysis (frequency information):
  - Set **MODE** to **FFT:**

  - Set FFT configurations **(HOLD to Max, SPAN to 40 kHz).**
- For time information:
  - Set **MODE** to **TIME:**



- Press the **LOG** button to start the measurement for the set time duration:



DC magnetic field measurements (Pacemaker limits), AC H field FFT measurements, and Weighted Peak measurements (ICNIRP 98 Public limits).

Note: The general public limits are used in both zone A and zone B as worker area do not necessarily refer to only EMF workers. Drivers and technicians can be members of the general public (for example, users of pacemakers and other AIMDs, etc), so the public limits are used in either case.

5. Details about the measurement (such as date, test set-up, environmental conditions, results and procedures followed) must be recorded in a report, which must also include a measurement uncertainty calculation. The typical uncertainty for the SMP3 + WP400 is ± 0.6 dB (7.2 %) and ± 0.39 dB (4.5 %) for SMP3 + WPH-DC.

Conclusion:

This application note covers measurement of electromagnetic field generated inside and outside a rolling stock using the portable SMP3 meter + WP400/WP10M and WPH-DC probes from Wavecontrol in accordance with the international IEC 62957 and European EN 50500 standards.

The current document is targeted towards Rolling stock manufacturers and inspectors/auditors. The goal is to perform a complete evaluation of the EMF exposure in all the critical areas that could lead to overexposure of users of the railway system

The proposed instrument from Wavecontrol complies with all the requirements specified in the railway standards and also, the IEC 61786-1 standard for performing compliance check in the railway industry. Moreover, it gives additional features such as Weighted Peak Method, list of different international and regional exposure limits, frequency bandwidth selection to specify measurements according to the frequency range (up to 20 kHz) required in railway applications. The device is also compatible with numerous accessories like the tripod and horizontal probe extension for correct placement of heights and distances.

References:

1. IEC 62597:2019 “Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure”. [EN 50500:2008 “Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure”]
2. CENELEC: Comité Europeo de Normalización Electrotécnica (www.cenelec.eu)
3. IEC: International Electrotechnical Commission (www.iec.ch)

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